Repeaters using new digital voice technologies such as DMR, D-STAR or System Fusion are much more spectrum-efficient than their analog FM cousins. But integrating narrower-bandwidth repeaters into existing band plans is a challenge. K2ATY has studied the issue and proposes one solution.

Narrowbanding – Amateur Radio Style

BY ALFRED T. YERGER, II,* K2ATY

As demand for spectrum increases, particularly on the higher frequencies, the trend in land mobile radio (LMR) has been toward *narrowbanding*. The purpose of narrowbanding is to utilize less radio spectrum per QSO or, looking at it another way, more QSOs per MHz. This concept is far from new. In the early days of FM communications, channels were spaced 60 kHz apart and there was no real specification for how far from the center frequency the FM carrier could be deviated or modulated. Things eventually settled down and FM deviation was standardized at ±15 kHz. This might be considered the first narrowbanding of VHF land mobile radio. As the use of FM grew, the next phase of narrowbanding came when the FM deviation was reduced from ±15 kHz to ±5 kHz. In addition, channel spacing on the commercial VHF low band (30-50 MHz) was reduced from 60 kHz to 20 kHz, a three to one split: And the channel spacing on most of the high VHF band (150 to 173 MHz) was reduced to 30 kHz. As activity continued to increase, the channels on VHF high band were split again to 15 kHz in some areas. VHF high band was utilized by various services and each had its own frequency plan. Today, this results in a mix of channel spacing schemes. However, for a long time, the majority of the band utilized 15-kHz channel spacing, which amateur radio adopted for FM repeaters between 146 and 148 MHz.

Today, the majority of the commercial VHF high band has been split again to 7.5-kHz channels. To accommodate this even narrower spacing, conventional FM is being replaced with various digital modulation techniques, the goal being to achieve the equivalent of 7.5-kHz bandwidth per conversation. The UHF land mobile band has seen channel spacing split from 25 kHz to 12.5 kHz and now down to 6.25 kHz.

When the commercial channels are split, it is usually done in a manner that permits current users of the channels to maintain their channel center frequency but requires them to adopt a new, narrower, technology. This creates additional channels in between the existing channel centers. *Figure 1* illustrates the commercial migration to narrower channels in which 25-kHz channels are each split into two 12.5-kHz channels.

For this to work properly and maintain relatively interference-free operation, all of the current users need to adopt narrowband technologies prior to the "new" channels being assigned. *Figure 2* shows what might happen if some of the incumbent users fail to adopt the new technology prior to the new systems becoming operational on the split (or splinter) channels.

The user on the original center channel, having adopted narrowband technology, should continue to enjoy relatively interference-free operation. However, the two new narrowband users, along with the existing systems that have not

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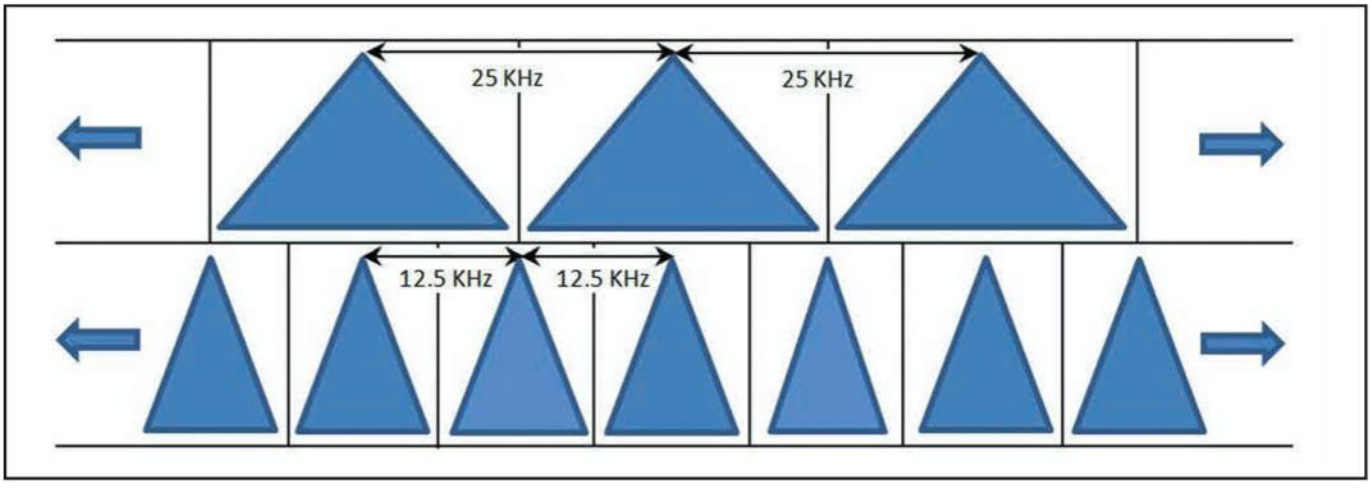

Figure 1. Commercial migration to narrow channel spacing.

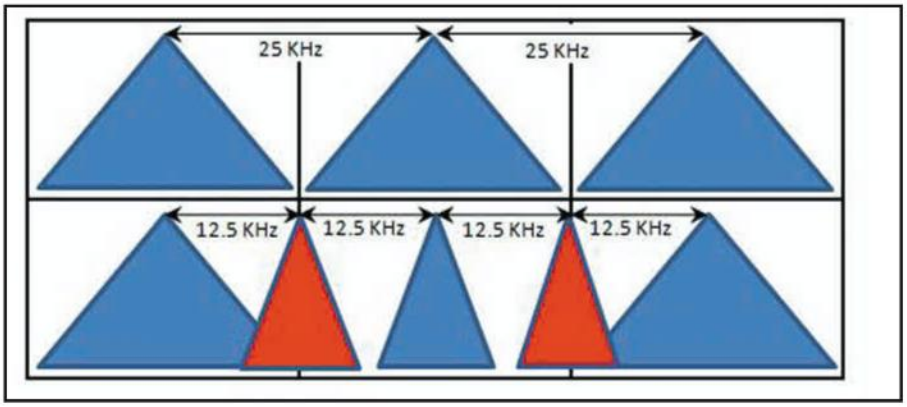

Figure 2. New narrowband systems before existing stations convert. Note potential for interference between narrow and wideband repeaters.

adopted the new technology, will now experience interference due to the overlap of their signals.

Amateur Radio Narrowbanding

Amateur radio is also experiencing its own form of narrowbanding. With the advent of digital mobile radio (DMR) under names like MotoTRBO, D-STAR, System Fusion, etc., we are seeing a rapid growth of new systems on the VHF and UHF bands that occupy significantly less spectrum than existing analog FM systems. DMR (which we're using generically in this article) conserves spectrum in two ways.

First, each station occupies half the bandwidth of conventional FM. *Figure 3* illustrates how two DMR signals can exist in the space previously occupied by one FM signal. Currently in the FM portion of the 70-centimeter amateur UHF band, repeaters are spaced 25 kHz apart. DMR stations, on the other hand, can be spaced 12.5 kHz apart.

In addition to the narrow bandwidth of DMR, through the use of time division multiple access (TDMA), each station can also support two simultaneous QSOs. This results in a 400% increase in spectrum utilization, giving us the equivalent of a 6.25-kHz channel bandwidth. In other words, one DMR QSO for every 6.25 kHz of spectrum as compared to one FM QSO for every 25 kHz of spectrum.

Amateur Narrowbanding Issues

In commercial systems, the move to narrowband technology is usually driven by changes in regulations requiring systems to implement a new technology by a certain date[1]. Now this doesn't happen without some pain and anguish, but there is nothing like a deadline to get things done. In amateur radio, we have a different motivation. Our change to narrow bandwidth technologies is driven by our desire to experiment with new technologies, accommodate more systems, reduce interference, and take advantage of new features offered by the new modes. Yes, the commercial users have some of these same desires but hams lack the extra push created by changes in FCC rules. In fact, FCC rules often hold us back while we wait for new emissions to be approved for use in the amateur bands.

All of this means that our migration from one technology to another will be slower and that not everyone will want to adopt the new modulation. As such, while supporting and encouraging the new, we need to be considerate of both the old and the new in our band plans.

Amateur UHF Band Migration

For the purposes of this discussion we will use the 70-centimeter amateur UHF band as an example (2 meters has some other issues that we will address later). As indicated above, repeater frequencies at 440 are generally 25 kHz apart. In most metropolitan areas, there are very few open channels to accommodate new systems, so when a DMR repeater is constructed, it is often replacing an existing FM system. The FM system likely operates on a frequency that

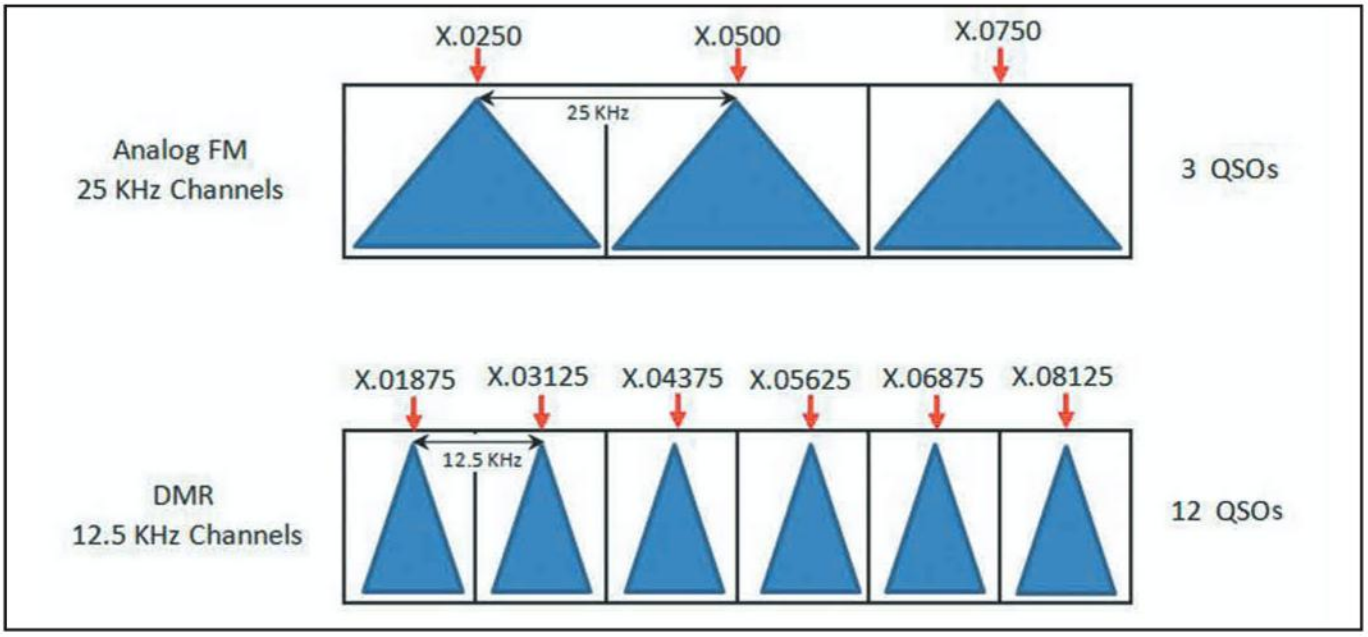

Figure 3. Analog FM vs. DMR spectrum utilization.

has been coordinated by the local coordination council and it is logical that the DMR users would want to utilize the same channel center frequency. In *Figure 4*, we show three hypothetical frequencies with 25-kHz spacing. The X represents the MHz portion of the frequency. For this example, the value of X is not really important. The diagram illustrates the channel utilization when the repeater on X.0500 MHz (the middle channel) changes from FM to DMR.

When the repeater on X.0500 changes from FM to DMR, additional spectrum is made available on either side. The problem is that the space on either side is too small for another DMR repeater and way too small for an FM system. If we continue to follow this "commercial" type migration plan, we will run into the same problems described above and illustrated in *Figure 2*. While this sometimes happens in commercial migrations, it is eventually resolved once everyone is onboard with the new technology. In amateur radio, on the other hand, there is no guarantee that the systems on X.0250 MHz and X.0750 MHz will adopt a narrowband technology. This doesn't make them bad people. They may stay on FM or eventually adopt a different technology, such as a 4-slot TDMA, that also has 6.25-kHz equivalent spectrum utilization but their footprint around X.0250 MHz or X.0750 MHz might remain unchanged. For DMR to be effective in increasing spectrum efficiency, we need a way to recover the extra space.

The extra space between the DMR signal and the existing FM signals can be recovered by offsetting the DMR signal by 6.250 kHz, either up or down, within the original 25-kHz channel. This makes space for a second DMR system. *Figure 5* illustrates two DMR signals, one at X.04375 MHz and the other at X.05625 MHz, in the 25-kHz channel formerly utilized by the FM repeater on X.0500 MHz.

One More Issue

In the 70-centimeter ham band, we have one more issue that our commercial friends do not. This is the presence of repeaters with reverse splits. In the commercial world, UHF repeaters transmit on the lower of the two frequencies in a pair and receive on the higher frequency, for example 452.000 MHz TX and 457.000 MHz RX. When the problems of amateur frequency coordination were originally addressed back in the 1970s, there was a disagreement about whether amateur repeaters should transmit low or transmit high. Eventually, in a compromise deal, repeaters on exact 50-kHz channel spacings would transmit low and repeaters on the 25-kHz channels in between would transmit high. Those of us who disagreed with this arrangement pointed out that this placed every repeater receiver in between two repeater transmitters. However, democracy being what it is, the compromise prevailed and I have to admit that there have not been a tremendous number of problems over the years, until now. This concept of every other

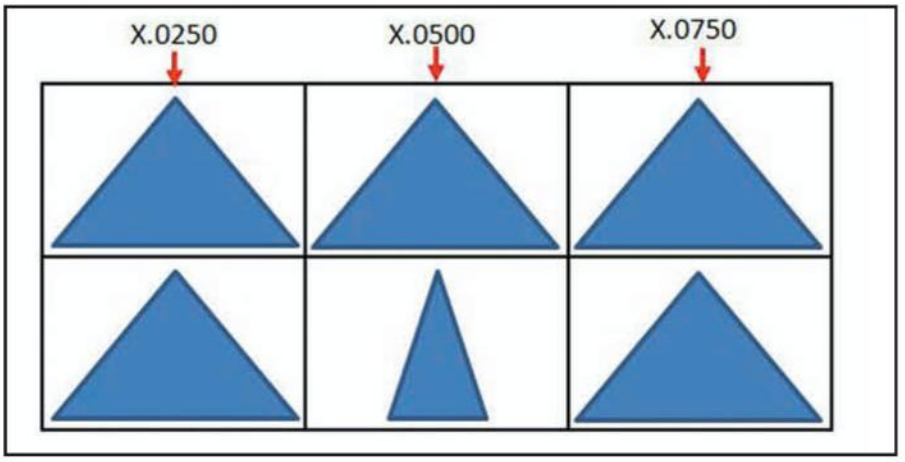

Figure 4. Initial amateur migration from FM to DMR, based on 25-kHz wide channels.

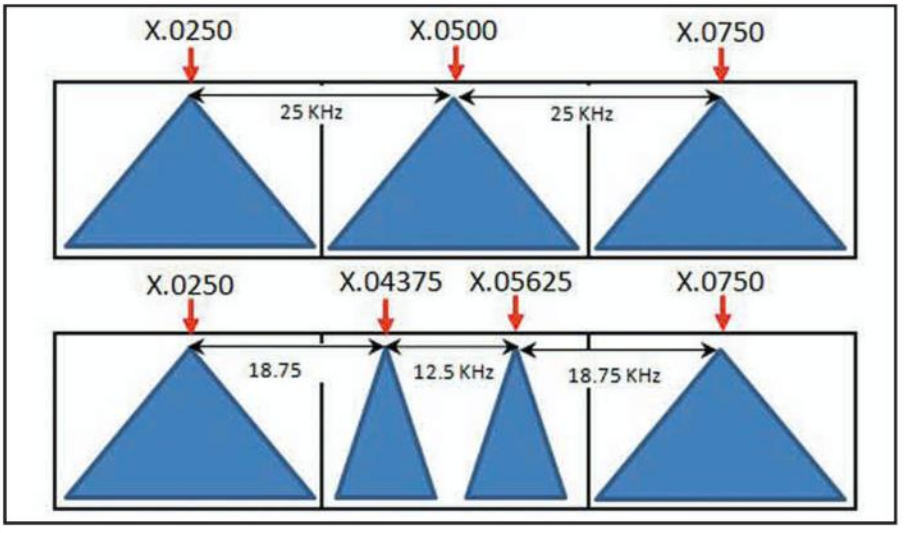

Figure 5. Amateur DMR offset migration; see text for discussion.

DX World Guide

By Franz Langner, DJ9ZB

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repeater pair being inverted all but forces us to avoid the commercial migration plan and adopt the offset migration plan shown in *Figure 5*. If we try to keep the current channel center frequencies for existing repeater frequencies being migrated to DMR, the interference shown in *Figure 2* will be extremely bad. In the commercial plan, even if this interference occurs, we would be looking at repeater outputs competing with each other. With the amateur inverted frequency plan, we would be looking at repeater outputs from superior sites splashing into the receive passband of other repeaters, also at superior sites. This would create a totally unmanageable situation.

Amateur 2-Meter Migration

Earlier we said that the 2-meter band had different issues. In many parts of the country, the FM repeater frequencies above 146 MHz are spaced at 15 kHz (other regions have 20-kHz separation, which is not a problem in this regard). The 15-kHz spacing is actually a little too narrow for 5-kHz deviation FM but it has worked out OK in the long run. Now…if you split the 15-kHz channels you get two 7.5-kHz channels, which are also too narrow for DMR. I don't know what is happening everywhere in the country (or world), but in New England, repeater coordinators are having good success with 10-kHz channel spacing on the lower end of the band from 145.000 to 145.600 MHz, with the traditional 600-kHz transmit-to-receive offset, and between 146.000 and 146.500 MHz with a 1-MHz transmit-to-receive offset.

With regard to the channels in the upper portion of the band that are currently utilizing 15-kHz channel spacing, the best plan seems to be to maintain the existing 15-kHz channel centers. Two adjacent 15-kHz channels would split nicely into three 10-kHz DMR channels but that would require the existing users of both channels to agree to migrate to DMR. However, once two adjacent channels are utilized for DMR on the current 15-kHz centers, both channels could move frequency slightly and allow for a third DMR system.

Summary and Recommendations

In the 70-centimeter amateur UHF band, the best plan for migrating to narrowband DMR is the offset plan in which DMR repeaters are spaced either 6.25 kHz below or 6.25 kHz above the existing FM channel center frequency. On the 2-meter band, current 20-kHz channels should be split into two 10-kHz channels using the same offset-type migration as on UHF, except that — in this case — the new channel centers will be 5 kHz above and 5 kHz below the old channel center. The current 15 kHz channels should remain on their existing channel centers until enough systems have migrated to DMR to allow adjacent pairs of channels to be split into three 10-kHz DMR channels. While we can't force amateurs to do anything, I would strongly recommend that all new DMR repeaters adopt these plans when first activated and that existing DMR systems move to these plans as soon as practical. This will reduce the problem of requiring all of the users of the new systems to reprogram their radios when the inevitable frequency changes take place.

Acknowledgement:

I would like to thank Bill Barber, NE1B, for his assistance in preparing this article and all of his good work promoting amateur DMR.

Note:

1. FCC mandatory narrowbanding Report and Order for compliance Jan.1, 2013.